EFFECT OF REPEATED RESIDENCE IN MOUNTAINS ON THE TOLERANCE OF MOUNTAIN CLIMBERS TO ACUTE HYPOXIA

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ABSTRACT: This research was conducted with 12 mountain climbers who were master athletes. Before and after the high-altitude expedition in the region of Tyan'-Shan' (maximum altitude 6995 m) their altitude tolerance was determined under conditions of gradual ascent in a pressure chamber and their blood was examined.

It was established that a visit of 5 - 6 weeks by the mountain climbers who had previously participated numerous times in high-altitude ascents, produces a relatively insignificant increase in their tolerance to acute hypoxia. No correlation was established between the increase in altitude ceiling and changes in the blood: increase in the number of erythrocytes and the hemoglobin.

Earlier we showed that the tolerance of mountain climbers to acute oxygen starvation is considerably higher than in those unadapted to high-altitude conditions (control group). The idea naturally arises that residence at high altitudes each time produces certain adaptation changes in the organism which can be summarized. In this respect it is of definite interest to study the altitude tolerance of mountain climbers before and after repeated residence at high altitudes. In the literature available to us we were unable to find any special research devoted to this problem. The authors who studied the increase in tolerance of healthy subjects after residence at high altitudes in the majority of cases made their observations on members of the scientific expeditions, i.e., on persons as a rule who had previously not been specially acclimatized to high-altitude conditions [1-6]. One exception only is the investigation of Hartmann et al. [7] who worked with a group of young men (8 subjects), who had been occupied for a rather long period of time with mountain climbing. Let us note that in these research projects, after residence in mountains following different periods of time subsequent to decent from high altitudes, there was noted a differently expressed increase in the altitude tolerance. According to the data of Hartmann et al. after prolonged residence in the Himalayas (4 months) including a period of several weeks at altitudes on the order of 6000-7000 m the altitude tolerance in 7 out of 8 subjects was increased. This increase was established after 1.5-2 months following return from the mountains but it was relatively small.

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Here it is significant that it was not possible to detect a strict correlation between the duration of residence of the subjects at high altitude and the respective increase in tolerance to acute oxygen starvation. This latter probably is due to the extremely prolonged residence of the expedition at high altitudes.

The basic task of the present paper was to study the effect of repeated residence under high-altitude conditions on the tolerance of mountain climbers to acute hypoxic hypoxia. With this purpose in mind, after 18-23 days following return from the mountains in 12 of the mountain climbers we made a determination of their altitude tolerance under conditions of gradual "ascent" in a pressure chamber. We can judge the conditions of acclimatization at high altitudes from the fact that it was carried out in the region of Tyan'Shan' where 5 subjects made an ascent to the top of Khan-Tengri (6995 m) but the basic group, who did not participate directly in reaching the peak, remained for a long period of time at altitudes of 4000-6000 m, periodically carrying out heavy physical work.

The methods of the investigation, directed at the establishment of an "altitude ceiling", i.e., the boundaries of the individual altitude tolerance, have already been described in a previous report and we shall not pay any special attention to them here. To set forth this research it is feasible to begin from the data which characterized the altitude tolerance before and after residence at high altitude. We can judge the changes in the altitude tolerance in 12 mountain climbers after 3 weeks following the high-altitude expedition based on data which are presented in Table 1 where the properties which characterize altitude and time of residence there are given for all subjects before and after residence at high al- /67
titudes.

As is obvious from the Table, in 9 of the subjects following residence in the mountains, a small increase was noted in the "altitude ceiling", and in 3, these facts are of definite interest; therefore let us look briefly at the characteristics of these subjects. In the mountain climber D-n the Adams-Stokes syndrome appeared. During his ascent in the pressure chamber to an altitude of 7000 m, a progressive decrease appeared in the pulse rate on the EKG after 25 sec. A rapid descent from high altitude then followed. In the process of descent, the heart activity suddenly ceased in the subject. The heart stoppage continued for 18 seconds and was accompanied by loss of consciousness and a spastic seizure in the form of an epileptic spasm. After 3-4 sec following disappearance of the pulse, sharp changes appeared in the bioelectric activity of the brain. After a short phase of hypersynchronization, an almost complete inhibition of the biopotential of the brain (Fig. 1) appeared. On the figure are shown the recordings of the EKG, EEG and breathing movements, taken at an altitude of 7000 m.

We can distinctly see the gradually increasing slow heart activity, the cessation of the heart with the simultaneous appearance of high amplitude flow oscillations on the EEG and finally the de-

TABLE 1. TIME (In Min and Sec) OF RESIDENCE OF MOUNTAIN CLIMBERS AT VARIOUS ALTITUDES DURING "ASCENT" IN A PRESSURE CHAMBER BEFORE AND AFTER HIGH ALTITUDE ASCENT.

Subject	7000 m		8000 m		9000 m		10,000 m	
	Before	After	Before	After	Before	After	Before	After
S-t	-	-	-	-	1.00	5.00	-	-
B-dt	-	-	-	-	2.00	5.00	-	-
Ts-in	-	-	-	-	1.10	5.00	-	-
T-m	-	-	-	-	1.30	3.00	-	-
B-yev	-	-	-	-	2.00	5.00	-	-
B-ov	-	-	-	-	2.30	-	-	1.30
M-yn	-	-	-	-	1.20	3.00	-	-
B-in	-	-	-	-	2.00	5.00	-	-
L-ov	25.00	30.00	-	-	-	-	-	-
K-ov	-	-	3.00	5.00	-	-	-	-
Ts-ov	4.00	3.00	-	-	-	-	-	-
D-n	0.40	-		-	-	-	-	-

velopment of biopotentials of the brain: on the EKG are seen the /68
first heart contractions. The beginning of the pulse rate was on the order of 30 beats/min and then gradually increased and after 30 sec reached 54 beats/min. After 1.5-2 minutes, the consciousness and the active condition was restored in the subject but still for a period of several minutes we noticed a certain weakness and slow-down. Thus in this case we may speak essentially about a man with grave functional disorders in the nervous regulation of the cardiac activity. It is interesting that this subject, who was a master athlete, during the period of residence at high altitudes up to 6200 m, retained a sufficiently good state of being and was able to /69
carry out heavy physical labor with which he managed (in the opinion of the other members of the expedition) even better than the others. With repeated ascent in a pressure chamber it seems maximal caution was exercised and, in particular, continuous registrations of the EKG were carried out due to which (unlike the first test) at the very beginning of development of bradycardia the subject was given oxygen which prevented the development of deep disruptions in cardiac activity (Fig. 2). It is significant that at this moment when a slight sharpening in the frequency of the heart contractions was noted in him, the subject indicated a deterioration in his state (nausea occurred). The second subject Ts-ov was a mountain climber /70
of the first category and also a highly qualified athlete.
The distinguishing mark of his body structure was the good development of his skeletal musculature. In this subject during the first

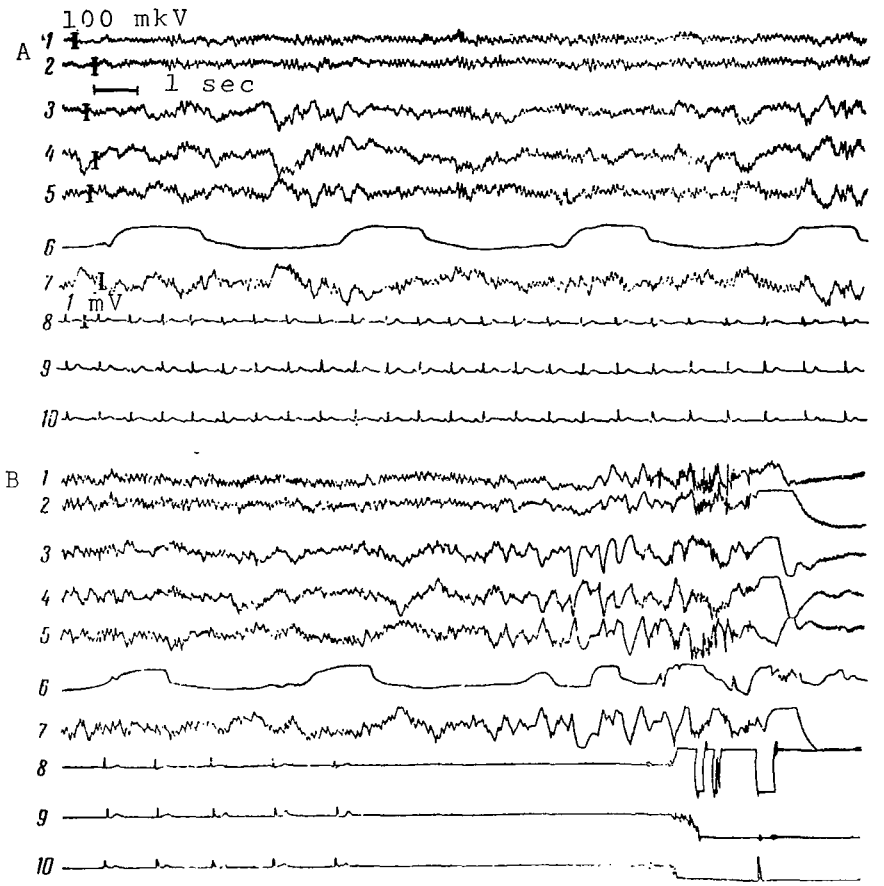

Fig. 1. EEG and EKG of the Subject D-n Before Residence at High Altitude. EEG: 1. Left Frontal Occipital; 2. Right Frontal Occipital; 3. Left Frontal Monoplar; 4. Right Frontal Monopolar; 5. Left Occipital; 6. Respiration; EKG: 8, 9, 10, I, II and III Standard Leads: A. Altitude 7000 m, 1-3 Minutes; B. 7000 m, 5th Minute.

ascent (prior to the expedition) an "altitude ceiling" of 7000 m was established where for 4 minutes there was observed in him a sharp slowdown chronic spasms of the muscles of the writing hand and a significant decrease in the level of consciousness. In this respect we made the recommendation to pay especially careful attention to the adaptation of Ts-ov to high altitude since it was found to be lower than in the other subjects. However in connection with the conditions constructed, Ts-ov was found to be in the front group and along with his companions reached the peak of Khan-Tengri. Here he felt so unsatisfactory that he could not descend from the peak alone. After 3 weeks following completion of the high-altitude expedition there was determined an altitude tolerance in the pressure

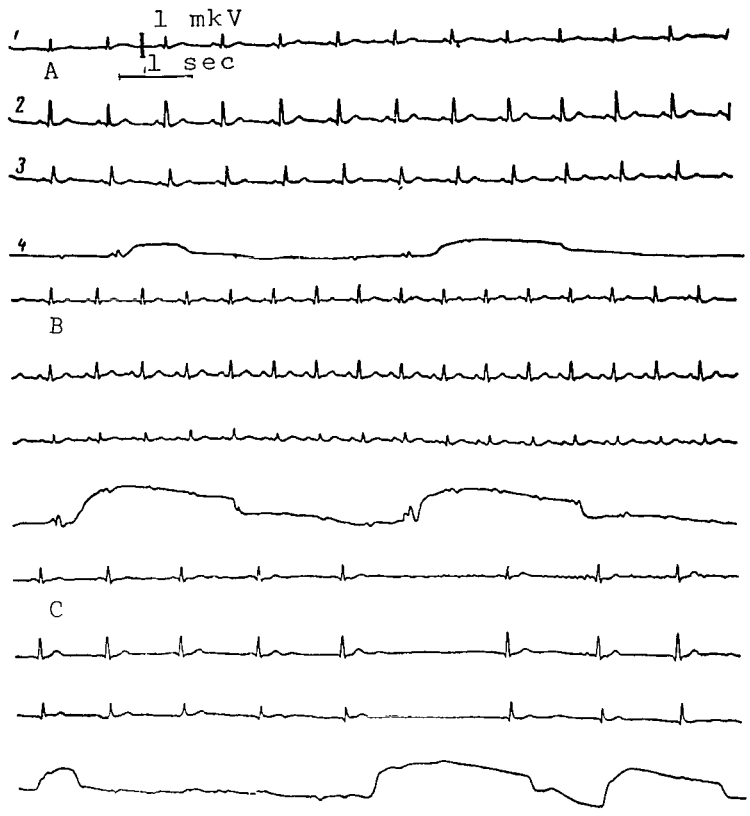

Fig. 2. EKG of the Subject D-n During Ascent to an Altitude of 6000 m Following Residence at High Altitudes. A. Before Ascent; B. 5000, m, 5-th Minute; C. 6000 m, 5th Minute. 1, 2, 3. I, II and III Standard EKG Leads; 4. Respiration.

chamber for Ts-ov. In the background recordings on the EKG there periodically appeared ventricular extrasystoles which in the first test had not appeared. At altitudes of 6000-7000 m the extrasystole was increased and there was noted a large localization of centers. At an altitude of 7000 m the subject remained approximately 1 minute less than before the ascent. The hypoxic state (symptomocomplex, characterizing development of deep disorders of the central nervous system) was the same as in the investigations carried out prior to the expedition.

In 9 of the subjects, as is obvious from Table 1, there was observed an insignificant increase in the "altitude ceiling". But they all noted that residence in the pressure chamber the second time adapted them easier than the first time and this difference was especially well expressed at altitudes of 6000-7000 m. We could even note slight divergences between the data of determining the "altitude ceiling" from the physiological characteristics and the

subjective evaluations of the results of the pressure-chamber investigations carried out before and after the expeditions.

It was interesting to compare several characteristics which characterize the functional state of the systems of the blood, respiration, blood circulation and the central nervous system with a given "altitude ceiling" before and after the expedition. These differences were found on the whole to be insignificant. One exception involved the data from the hemotological investigation (Table 2).

Although in 7 of the subjects there was established a slight increase in the "altitude ceiling", however no regular increase in the hemoglobin and erythrocytes was noted. Moreover it is of definite interest to look at the subjects (master athlete S-t and B-ov) in whom, after the expedition, both the hemoglobin and the number of erythrocytes were significantly decreased. At the same time they showed a higher tolerance to acute hypoxia. Thus in the mountain /71
climbers there was no correlation detected between the number of erythrocytes, the hemoglobin and the altitude tolerance. In comparing the data which characterize the functional stress of the internal breathing no substantial differences were observed in frequency, depth, amount of ventilation and saturation of arterial blood with oxygen before and after the high-altitude expedition.

TABLE 2. NUMBER OF ERYTHROCYTES IN THE HEMOGLOBIN OF MOUNTAIN CLIMBERS AFTER 21 DAYS FOLLOWING DESCENT FROM THE MOUNTAINS.

Subject	Hemoglobin, %	Erythrocytes, 1000	Subject	Hemoglobin, %	Erythrocytes, 1000
S-t	16,6 / 13,3	4410 / 3650	K-ov	14,0 / 16,0	4500 / 5050
M-in	16,6 / 17,7	4800 / 4850	B-in	13,3 / 17,3	4350 / 5050
T-m	14,6 / 14,3	6100 / 6500	B-v	15,0 / 10,3	4300 / 3300
B-ov	15,3 / 15,3	4400 / 4200			

Comment. The numerator is before residence in the mountains; the denominator is after residence.

It was also impossible to detect any substantial difference in the changes of frequency in the heart contractions on the EKG. Data from electroencephalographic investigations were also quite similar and only in individual subjects was there noted during the ascent in the pressure chamber after the expedition a somewhat more slightly expressed change in the biopotentials to the left, (the appearance of slow oscillations). Comparison of the recordings of the state

of being permitted us to make the conclusion that the change in handwriting with the second ascent was somewhat less expressed than in the first investigation. However, as noted previously, the subjects themselves noted that their state of being became somewhat better.

On the basis of analyzing the obtained data we may come to the conclusion that, in subjects who have been exposed repeatedly to high-altitude conditions and who already possess a high tolerance to hypoxia, residence in the mountains for a period of 5-6 weeks at altitudes up to 6000-7000 m produces only an insignificant increase in the "altitude ceiling". This gives a basis for assuming that a substantial increase in the altitude tolerance of mountain climbers occurs apparently as a result of the first 3-4 times in the mountains after which the increase in tolerance is no longer significant.

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